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SUSY SEARCHES IN COMBINED LHC/LC ANALYSES

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We present a case study for the synergy of combined LHC and LC analyses in Susy searches in which simultaneous running of both machines is very important. In this study only light non-coloured Susy particles are accessible at a Linear Collider with an initial energy of $\sqrt{s} = 500$ GeV. Nevertheless the precise analysis at the LC leads to an accurate Susy parameter determination and prediction of heavy Susy particles. Providing these LC results as input for the LHC analyses could be crucial for the identification of signals resulting in a direct measurement of the heavy neutralinos. The interplay of the LHC and LC will thus provide an important consistency test of the underlying model.

1 Introduction

In the Minimal Supersymmetric Standard Model (MSSM) one is faced with around 105 new free parameters. They have to be precisely determined at future experiments in order to reveal the underlying structure of the model. Due to the clear signatures at the Linear Collider (LC) a largely model-independent determination of masses, couplings, mixing angles, phases and quantum numbers of kinematically accessible particles can be done. Assuming the LHC running to overlap with the first stage of a LC with $\sqrt{s} = 500$ GeV (LC₅₀₀), significant impact of LC₅₀₀ on the LHC analyses is expected. For the reference point SPS1a² we show how measurements of the light chargino/neutralino states at the LC₅₀₀ may help identifying signals of the heavy neutralinos produced at the LHC and consequently improve their mass measurement. Conversely, the LHC results will increase the precision of Susy parameter determination at the LC. The interplay of both colliders will therefore provide a powerful consistency check of the model and may outline future strategies for new physics searches at the LHC¹.

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2 Susy Analyses At The LHC And The LC

LHC Susy studies:

Detailed simulations of the LHC capabilities for the reference point SPS1a² were carried out³; the masses of the Susy particles can be studied by analysing complicated decay chains, like $\tilde{q}_L \rightarrow \tilde{\chi}_2^0 q \rightarrow \tilde{\ell}_R^\mp \ell^\pm q \rightarrow \tilde{\chi}_1^0 \ell^\mp \ell^\pm q$ and $\tilde{q}_L \rightarrow \tilde{\chi}_4^0 q \rightarrow \tilde{\ell}_R^\mp \ell^\pm q \rightarrow \tilde{\chi}_1^0 \ell^\mp \ell^\pm q$, which might be difficult to resolve, in particular the latter one. A joint fit of various kinematic ‘edges’ yields an overconstraint system and leads to an indirect knowledge on the mass of the lightest Susy particle (LSP) with, however, some assumptions about particle identities. We show in Fig. 1 (left) the strong correlation between the fitted values of $m_{\tilde{\ell}_R}$ and $m_{\tilde{\chi}_1^0}$. The precise reconstruction of the states in the decay chains requires in particular the knowledge of $m_{\tilde{\chi}_1^0}$. In the SPS1a reference point the heavy charged and the neutral gaugino/higgsino particles can lead to identical final states and the association of the edges to the corresponding sparticles is difficult. In combination with measured invariant masses one can derive the Opposite-Sign Same-Flavour (OS-SF) signal of the heavy particle with $\delta(m) = 5.1$ GeV, and under specific assumptions one can interpret the edge in Fig. 1 (right) as that of the $\tilde{\chi}_4^0$ particle^{3,4}.

LC₅₀₀ Susy studies:

The precise measurement of the masses as well as the production cross sections of the light non-coloured sparticles alone may lead to a rather precise determination of the fundamental Susy parameters which govern the chargino-neutralino sector (see e.g.⁶ and references therein). The masses of the heavier neutralinos and the heavier chargino can then be predicted.

In order to determine the parameters we exploit only $m_{\tilde{\chi}_1^\pm}$, $m_{\tilde{\chi}_{1,2}^0}$ and the corresponding cross section measurements at a LC with both beams polarised and take into account the simulated errors of all relevant masses⁵, $m_{\tilde{\chi}_1^\pm}$, $m_{\tilde{\chi}_{1,2}^0}$, $m_{\tilde{e}_{L,R}}$, $m_{\tilde{\nu}}$, 1σ statistical errors for the polarised cross sections (on a basis of 100 fb⁻¹ per each polarisation configuration), a polarisation uncertainty of $\Delta P(e^\pm)/P(e^\pm) = 0.5\%$ and estimated systematic errors¹.

Within the allowed error bars we derive a very accurate determination of the underlying fundamental Susy parameters, see Table 1 (2nd line) and get the following predictions for the heavier particles:

$$m_{\tilde{\chi}_3^0} = 359.2 \pm 8.6 \text{ GeV}, \quad m_{\tilde{\chi}_4^0} = 378.2 \pm 8.1 \text{ GeV}, \quad m_{\tilde{\chi}_2^\pm} = 378.8 \pm 7.8 \quad (1)$$

Combined LHC+LC₅₀₀ studies:

Feeding the results of the LC analysis as input into the LHC analysis improves the LHC analysis in several ways:

- increase of statistical sensitivity due to the mass predictions ('look elsewhere effect'), which could be crucial for the search for statistically marginal signals;
- clear identification of the dilepton edge from the $\tilde{\chi}_4^0$ decay chain, followed by an accurate measurement of $m_{\tilde{\chi}_4^0} = 377.87 \pm 2.23$ GeV;
- better accuracy also for $m_{\tilde{\chi}_2^0}$ (e.g. $\delta(m_{\tilde{\chi}_2^0}) = 0.08$ GeV) due the precise knowledge of the LSP mass, $m_{\tilde{\chi}_1^0}$.

The precise identification of a dilepton edge right at the predicted mass with the help of the LC means an important check of the underlying Susy model.

Using these improved results from the LHC analysis as input for further analyses at the LC leads also to an improvement in the Susy parameter determination, see Table 1, 3rd line.

3 Conclusions

The analysis has been performed within the general framework of the unconstrained MSSM. We focused on the situation where only the light states ($\tilde{\chi}_1^0$, $\tilde{\chi}_2^0$, $\tilde{\chi}_1^\pm$) are accessible at the first stage of the LC, as exemplified in the SPS1a scenario. The masses of heavier chargino and neutralinos can subsequently be predicted which in turn lead to an increase of statistical sensitivity and to a clear identification of the heavy particles in the corresponding decay chains at the LHC analysis. Feeding back the LHC results into further analysis at the LC₅₀₀ leads to an even more accurate model-independent determination of the Susy parameters. Such a combined study provides therefore a sensitive test of the model.

	M_1	M_2	μ	$\tan \beta$
input	99.1	192.7	352.4	10
LC ₅₀₀	99.1 ± 0.2	192.7 ± 0.6	352.8 ± 8.9	10.3 ± 1.5
LHC+LC ₅₀₀	99.1 ± 0.1	192.7 ± 0.3	352.4 ± 2.1	10.2 ± 0.6

Table 1: Susy parameters with 1σ errors derived from the LC data collected at the first phase of operation, and from the combined analysis of the LHC and LC₅₀₀ data.

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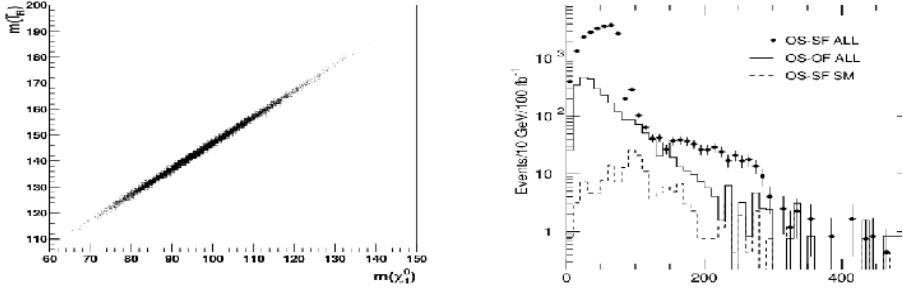


Figure 1: Mass measurements at the LHC^{3,4}: correlation of the fitted $m_{\tilde{l}_R}$ and LSP $m_{\tilde{\chi}_1^0}$ in the scenario SPS1a (left), and invariant mass spectrum of the heavy neutralino/chargino decay chains⁵ (right). The dilepton OS-SF lepton edge of $\tilde{\chi}_4^0$ is the edge between $200 \text{ GeV} < m_{ll} < 400 \text{ GeV}$.

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